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Technique for Changing the Valve Timing of an Internal Combustion Engine

The invention relates to a technique for changing the valve timing of an internal combustion engine according to the precharacterizing part of claim 1.

It is commonly known that the timing of an intake or exhaust valve of an internal combustion engine can be changed by first changing the position of the intake camshaft in relation to the exhaust camshaft by means of a camshaft actuator. The opening and closing times of the intake valves are thereby adapted to a certain RPM range by two separate intake timings and the valve overlap, while the valve opening duration and the valve stroke remain the same (see e.g. DE 38 76 762). Furthermore the prior art includes variable valve trains in which the valve opening times as well as the valve opening width are adapted to the operating mode of the engine. For example, DE 196 06 054 C2 describes a variable valve train of an internal combustion engine in which the valve stroke can be adjusted between two settings with the aid of a switchable bucket tappet. Said assembly is equipped with a device that adjusts the intake and exhaust times of the gas exchange valve, allowing improved filling of the cylinder over a large range of RPMs.

The object of the invention is to expand the functional range of a camshaft actuator in such a way that, in addition to adjusting the valve timing by “shifting” the valve stroke curve toward intake or exhaust for an “early” or “late” opening, an adjustment of the valve opening time can be achieved.

The invention teaches that this object can be solved through the features described in Claim 1.

For decreasing the valve opening time, the invention suggests adjusting the camshaft in the direction of “late” during a valve stroke while adjusting, that is, correcting the camshaft in the direction of “early” during the immediately subsequent base circle phase of the affected camshaft. To increase the valve

opening time, which is determined by the shape of the cam lobe, the invention suggests adjusting the camshaft toward “early” during a valve stroke while adjusting, that is, correcting the camshaft in the direction of “late” during the immediately subsequent base circle phase of the camshaft in question. By following these measures, the valve opening duration can be adjusted in an advantageous manner. With the uses of use of a camshaft actuator, a range of function is thereby achieved, which is otherwise possible only with a variable valve train system.

Based on the features described in the subclaims, additional advantageous configurations of the invention are also possible.

The technique for changing valve timing described in the invention is particularly suited for a double-rowed, 6-cylinder engine with a symmetrical ignition sequence per cylinder bank, since in engines of this type an even distribution of valve stroke and base circle phase on the camshaft are present.

The inventive procedure described is also suited for combination with a variable valve train, in which a valve stroke cross-over is present, because, as illustrated in the 2-setting valve cross-over exemplified in DE 196 06 054 C2, the base circle phase of the cam is especially long with the small valve strokes.

An embodiment of the invention is described in further detail in the following description.

The figure consists of a diagram showing the valve stroke on the intake side of the internal combustion machine as well as the angular velocity of the camshaft.

The inventive procedure is described based on a 6-cylinder boxer engine, both camshafts of which are equipped with camshaft actuator as well as a two-setting valve stroke change-over on the intake side. Internal combustion engines of this type are made by the Porsche Corporation under the model series 996 "VarioCamPlus-System." The construction and function of this variable valve train therefore does not need to be described in further detail. With the aid of a hydraulically- activated camshaft actuator, the valve timing can be continuously adjusted on the intake side, while, because of the 2-setting valve cross-over, valve stroke curve A can be adjusted with a small cam lobe and valve stroke curve B can be adjusted with a large cam lobe as the diagram illustrates. The valve timing as well as the valve stroke are controlled as a function of the operating parameters of the internal combustion engine such as load or RPM. A possible field of the valve train in which the various operating modes of the valve train are plotted as a function of RPM and load of the internal combustion engine is described and illustrated in DE 196 06 054 C2. As long as a continuous adjustment of the angle of rotation of the intake camshaft to exhaust camshaft and to crankshaft of the internal combustion engine is present, only valve stroke is shifted toward "early" or "late." The angular velocity of the camshaft is, up to the actual adjustment process, constant as shown in the dashed line C in the diagram.

Below the inventive procedure for decreasing or increasing the valve opening duration with the aid of a camshaft actuator is described in further detail. The technique is particularly useful, when the internal combustion engine is driven by small valve strokes, because the base circle phase of the "small cam lobe" is particularly long.

1. Decreasing the valve stroke curve.

During a valve stroke the intake camshaft is adjusted toward "late" in the amount $\Delta\varphi$, while attitude of rotational angle of the camshaft is reset, that is, corrected toward "early" during the immediately subsequent base circle, preferably in the amount $\Delta\varphi$. This process is repeated, provided that the valve opening duration for the current operating mode of the internal combustion engine is reduced relative to the "normal" valve opening duration, which is determined by the valve cam lobes. The valve opening, curve D, illustrated in the diagram is thereby yielded. Corresponding to valve opening, curve D, is the angular velocity of the camshaft, curve E, whereby it is evident that during the valve stroke a positive acceleration of the camshaft toward "late" occurs, while a negative acceleration of the camshaft toward "early" occurs due to the resetting during the base circle phase of the affected cam lobe.

2. Increasing the valve stroke curve

In this case, the camshaft is adjusted toward "early" in the amount $\Delta\varphi$ during the valve stroke, while the camshaft is corrected toward "late" during the base circle, preferably in the amount of $\Delta\varphi$.

The proposed procedure makes it possible to implement further valve stroke geometry with the same cam lobe shape. An influence of the valve stroke curve is then particularly important, if a high adjustment velocity can be implemented with the camshaft actuator. An electrically controlled camshaft actuator of the prior art is particularly advantageous in this respect. The previously described procedure is, as has already been mentioned, especially suited for double-rowed 6-cylinder engines without any restrictions to this configuration, because, in the case of the 1-6-2-4-3-5 ignition sequence used in the Porsche boxer engine, a symmetrical inanition sequence per cylinder bank can be produced thereby ensuring the even distribution of valve stroke and base circle phase on the camshaft. The procedure

can also be used on the exhaust side of the internal combustion engine, wherein the exhaust camshaft is also equipped with the necessary camshaft actuator in this case.